



U.S. Department of Energy  
Energy Efficiency and Renewable Energy

# Lighting Technology Update

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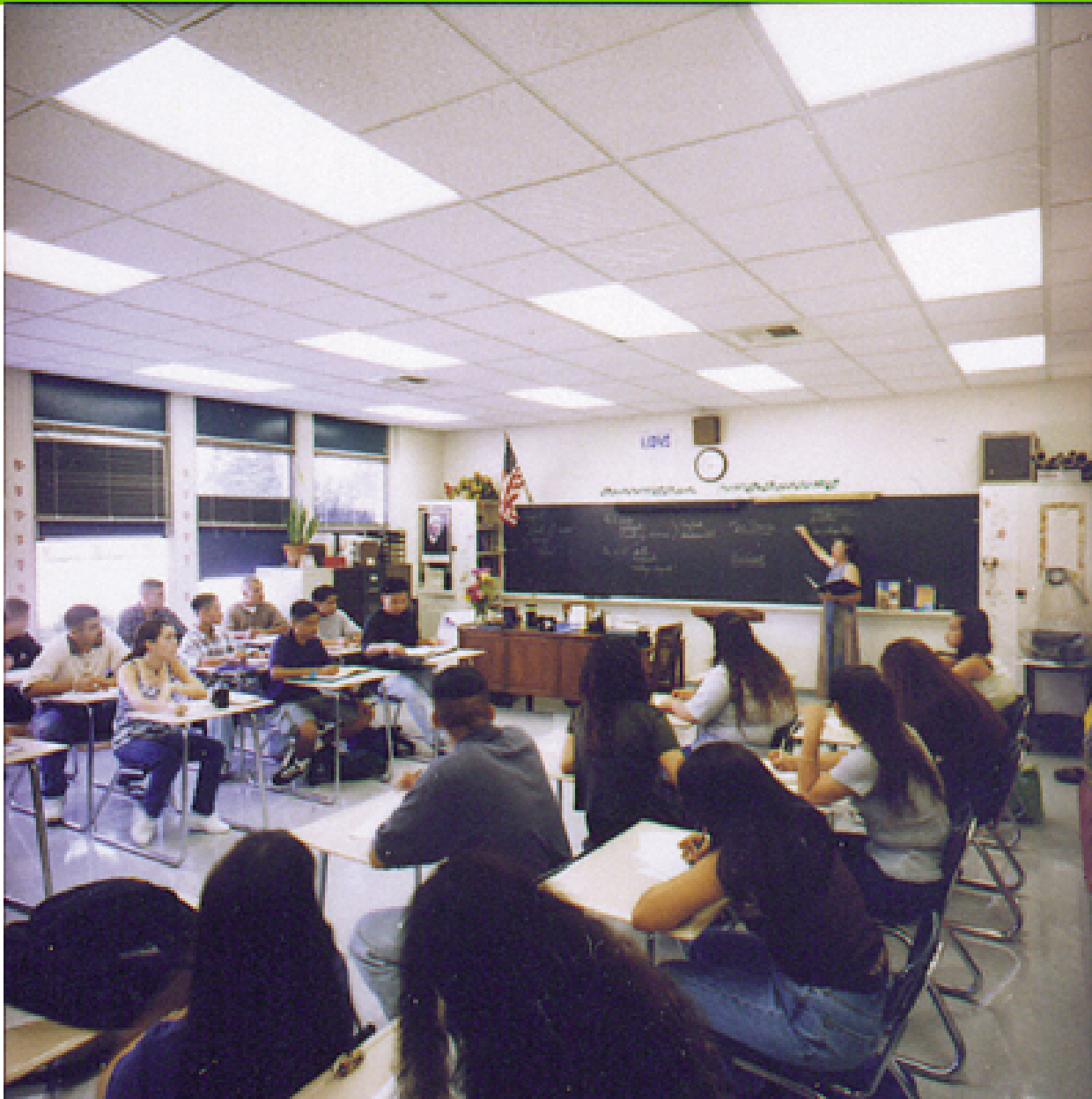
## The Hallmarks of "Good" Lighting

- Aesthetically Pleasing
- Energy Efficient
- Adequate Task Light Level
- Visually Comfortable
- Easy to Maintain
- Enhance Learning and Teaching Environment
- Minimal environmental impact

*Today's  
Lighting  
Technology  
can do this!*



*A room 25x30x12 feet in Central School, Glencoe, Ill., has an average intensity of twelve foot-candles provided by six 300-watt indirect units.*







# Technologies

- Incandescent/Halogen
- Fluorescent Systems
- Retrofit lamp and ballast types



## Principles of Operation

*Incandescent*

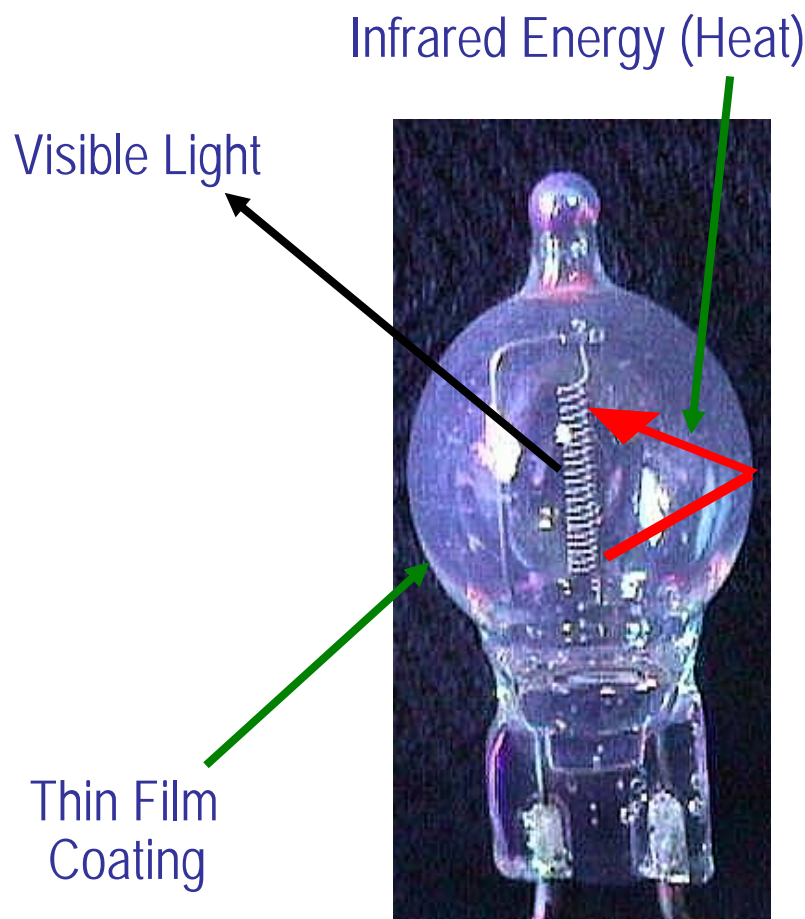


*Halogen*





## New Kid on the Block!



### IR Halogen Technology

- More visible light generated for each watt consumed
- Lower energy costs and less heat generated
- Multi-layered thin film Infrared coating on outer surface of halogen capsule
- Infrared energy (heat) is recycled within the IR capsule





# Technologies

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## The Lamps

*Linear Fluorescent*



*Compact Fluorescent*



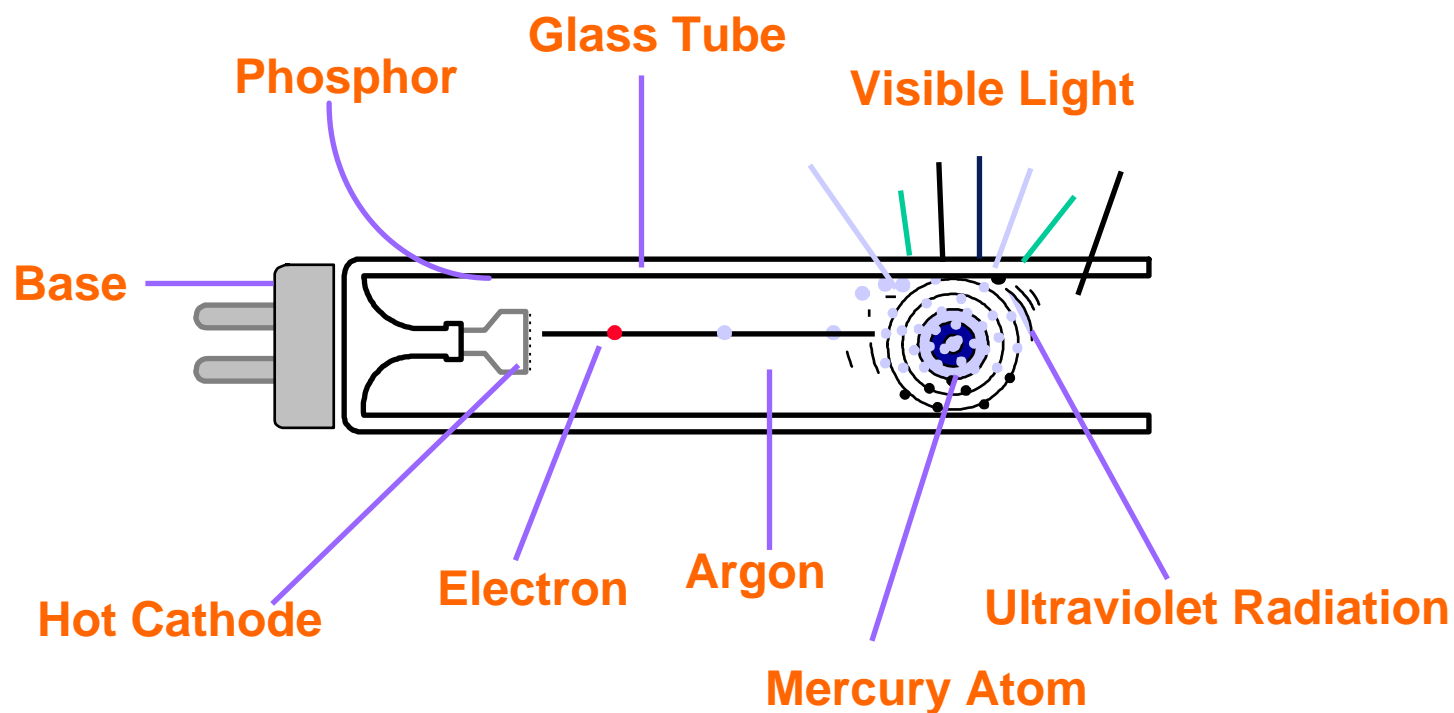


## The Fluorescent System





# Construction & Operation





# Lamp Basics

- **Lamp Efficacy**-- LPW--Lumens Per Watt
- **Lamp Life/Mortality**--The life rating for a fluorescent lamp is based on a 50% survival rate at three hours per start.
- **Lumen Maintenance**--The measurement of light output over the life of the lamp. The initial lumen rating is taken at 100 hours of operation.



# Lamp Efficacy

 Incandescent 10 - 30 LPW

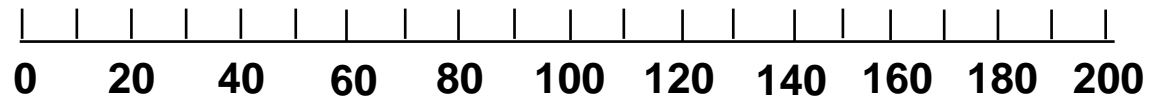
 Fluorescent 60 - 105 LPW

 Mercury 40 - 58 LPW

Metal Halide 67 - 115 LPW 

High Pressure Sodium 71 - 145 LPW 

Low Pressure Sodium 100 - 150 LPW 



*Lumens Per Watt - Including Ballast*

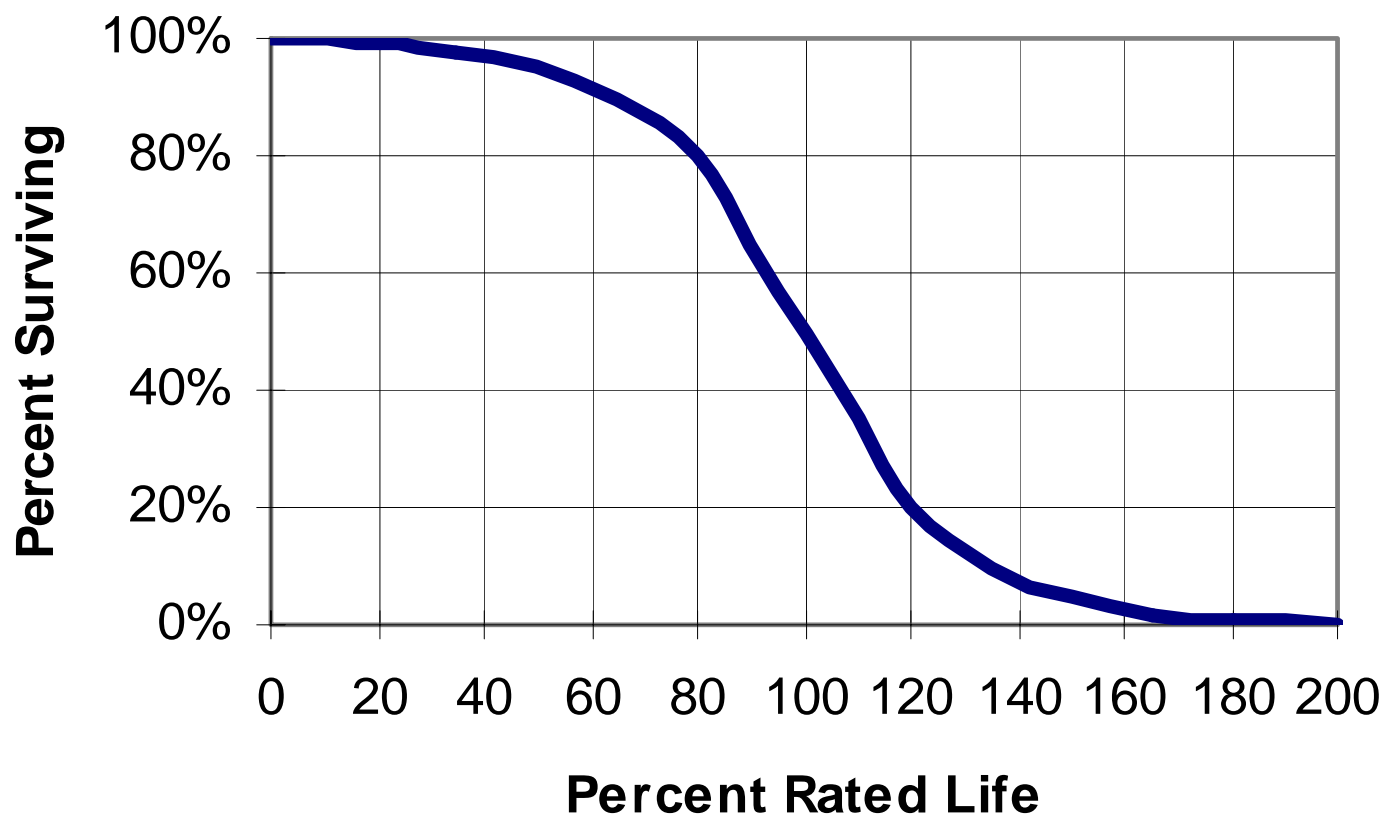


# Average Rated Life (hrs)

- Incandescent / Halogen---50% survive to life rating. Life is extended if voltage applied is below lamp rating.
- Fluorescent---50% survive to life rating @ 3 hours per start. Life is extended if starting times are longer.
- HID---50% survive to life rating @ 10 hours per start. Life is extended if starting times are longer.



## Typical Fluorescent Lamp Mortality







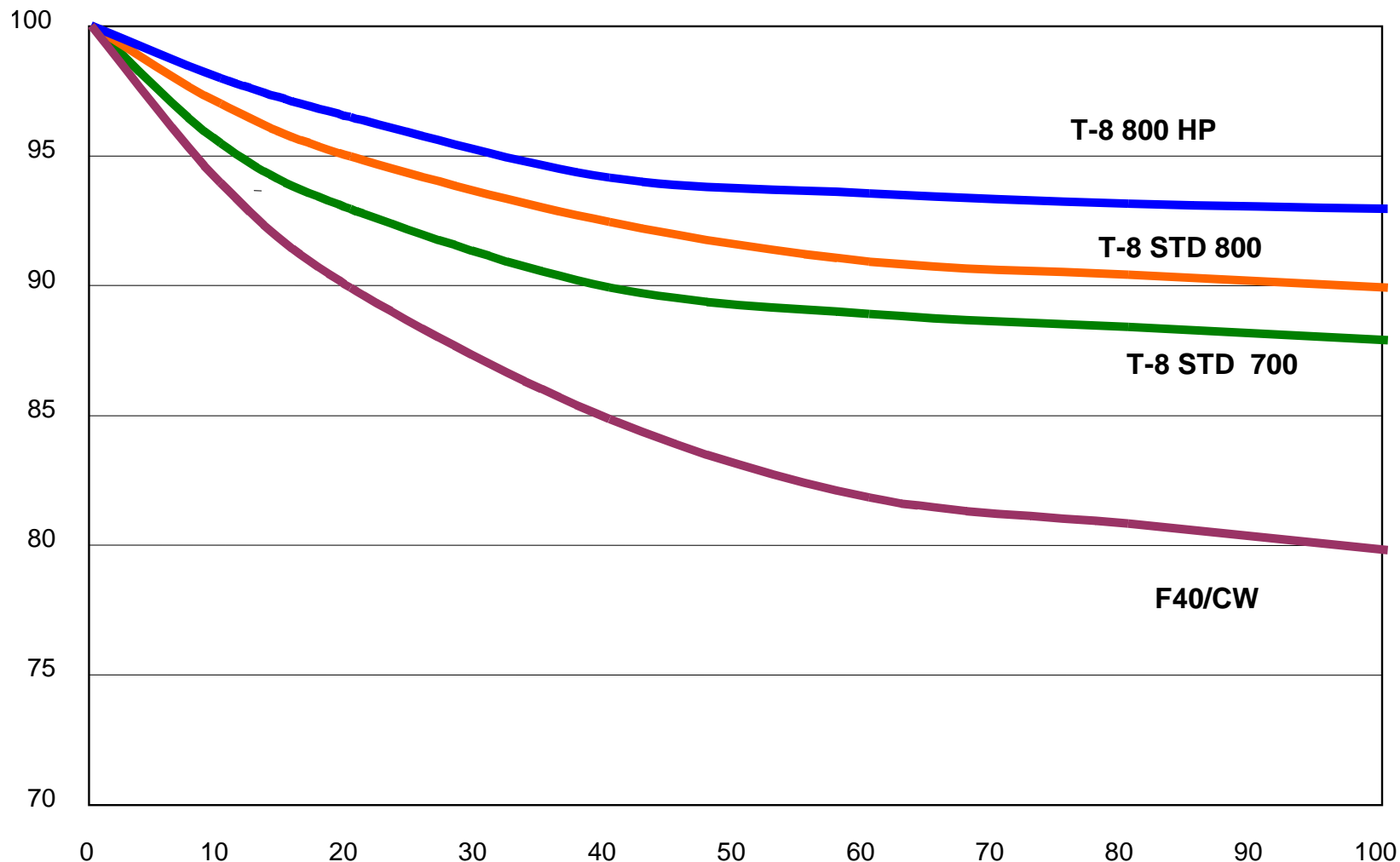
# Lumen Ratings

- Lumens---Light output in all directions. A dinner candle provides about 12 lumens. 100W A-line provides about 1750 lumens.
- Initial Lumens---Lumen output @ 100 hours of burning time.
- Mean Lumens---Lumen output @ 40% of the lamps rated life for Fluorescent and Metal Halide.



## T-8 Lumen Maintenance Curves (all values are listed in Percentages)

## Lumen Maintenance Comparison





## CRI---Color Rendering Index

- Suggests how an object illuminated by a light will appear under other common light sources.
- Scale of 1 to 100. 80+ is considered good.
- Halogen = 95-100, F40CW/SS = 62, FO32/700 = 75, FO32/800 = 82, and M400/U = 65.



# Temperature vs Fluorescent Lamps

- Will Fluorescent lamps start at any temperature???

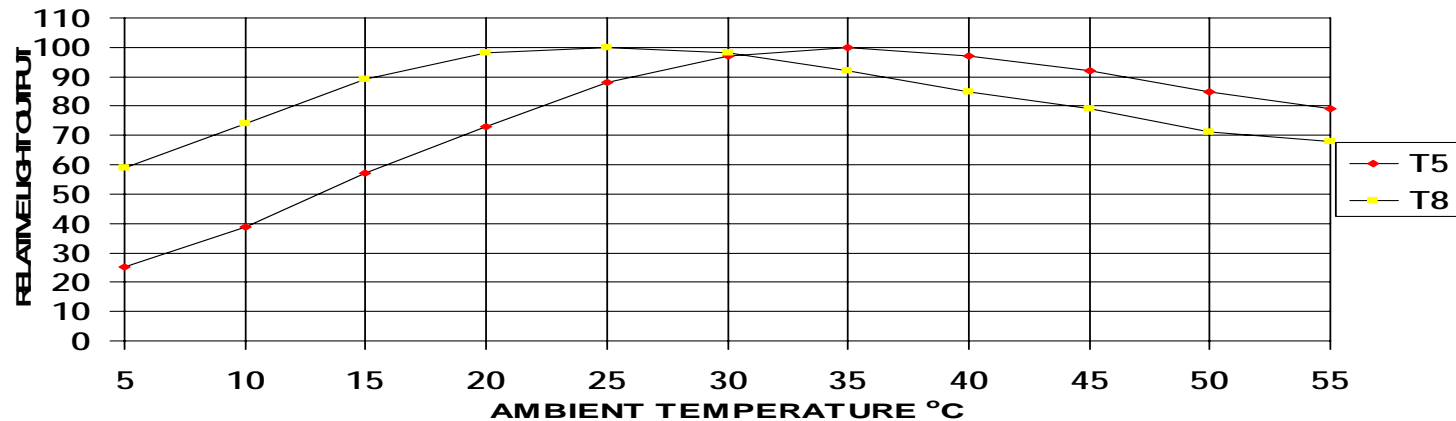
NO. Minimum starting temps for F34CWSS on ES Magnetic Ballast is 60 F. An FO32 T8 on IS Electronic Ballast is 0 F.

- Can Ambient Temperature change the lumen output of Fluorescent lamps???

YES, Almost all Fluorescent lamps are affected by Temperature.



# LUMEN MAINTENANCE T5 T8 BY TEMPERATURE

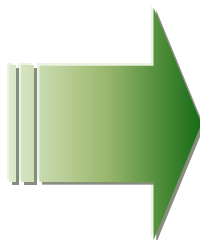




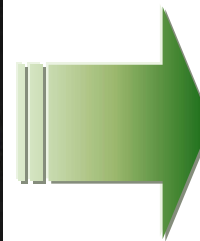
## Lamp technology has moved forward



1.5" T12



1.0" T8



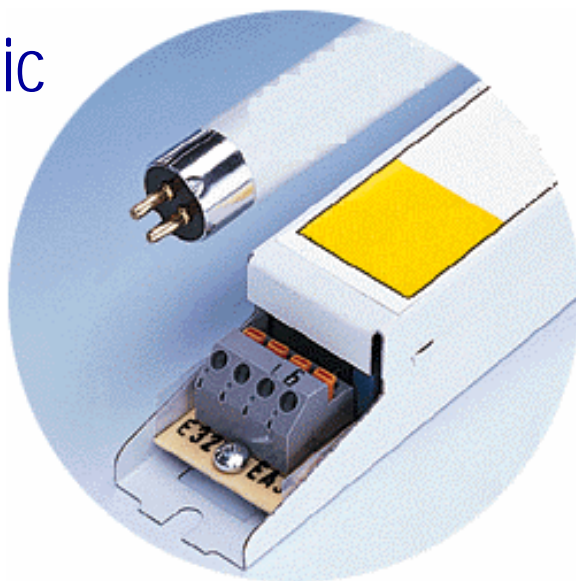
0.625" T5



## Fluorescent Ballast Types

- Magnetic
  - Standard
  - Energy-saving

- Electronic





## *Electronic Ballasts*

### *Advantages*

- Multiple lamp operation
- Very energy efficient
- Lower operating cost
- Relatively lightweight (potted/unpotted)
- Quieter and cooler operation
- Special functions/features available
  - Lamp End of Life Sensing
  - Programmed Starting
  - Dimming
  - Status Reporting
  - Universal input voltage

### *Disadvantages*

- Slightly higher per unit cost – lower per system cost

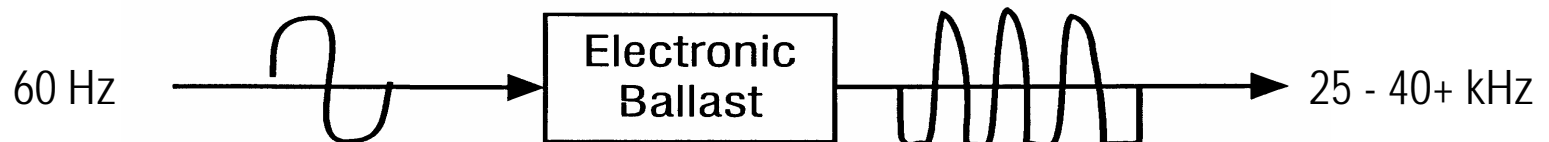
## *Magnetic Ballasts*

### *Advantages*

- Lower per unit cost

### *Disadvantages*

- Higher operating cost compared to Electronic
- Relatively heavy compared to electronic
- 1 or 2 lamp operation only
- Series lamp operation
- Recycling Issues (PCBs in older units)







## *Preheat Fluorescent Ballasts*

- Time delay to lamp start - flicker
- Cathodes are heated prior to lamp start (0.5-1.0s)
- Lamp start in 1.0 - 2.0 seconds
- 2 step process: Coil heat then OCV 0.7-2 kV applied
- External starter required

## *Rapid Start Fluorescent Ballasts*

- Cathodes are heated constantly by applying coil voltage
- Series operated
- Ground plane required for starting
- Operation down to 50°F

## *Instant Start Fluorescent Ballasts*

- Most energy efficient system- no cathode heating
- Discharge arc initiated by applying high OCV to jump start lamp
- Parallel operation
- Operation down to 0°F
- NEMA recommendation – shunted sockets for retrofit



## *Programmed Rapid Start Fluorescent Ballasts*

- Coil heat applied w/reduced or no open circuit voltage (OCV)
- OCV is then applied (After coils reach optimum temperature)
- Typically 50,000 to 100,000 start cycles
- Up to 250% longer life than current systems (IS/RS)
- Coil heat turned off or reduced after lamp starts
- Lower energy consumption than rapid start
- Longest lamp life in all applications
  - Including high switching cycles – Occupancy Sensors
- <10% THD
- Multiple ballast factor options 0.71 – 1.20

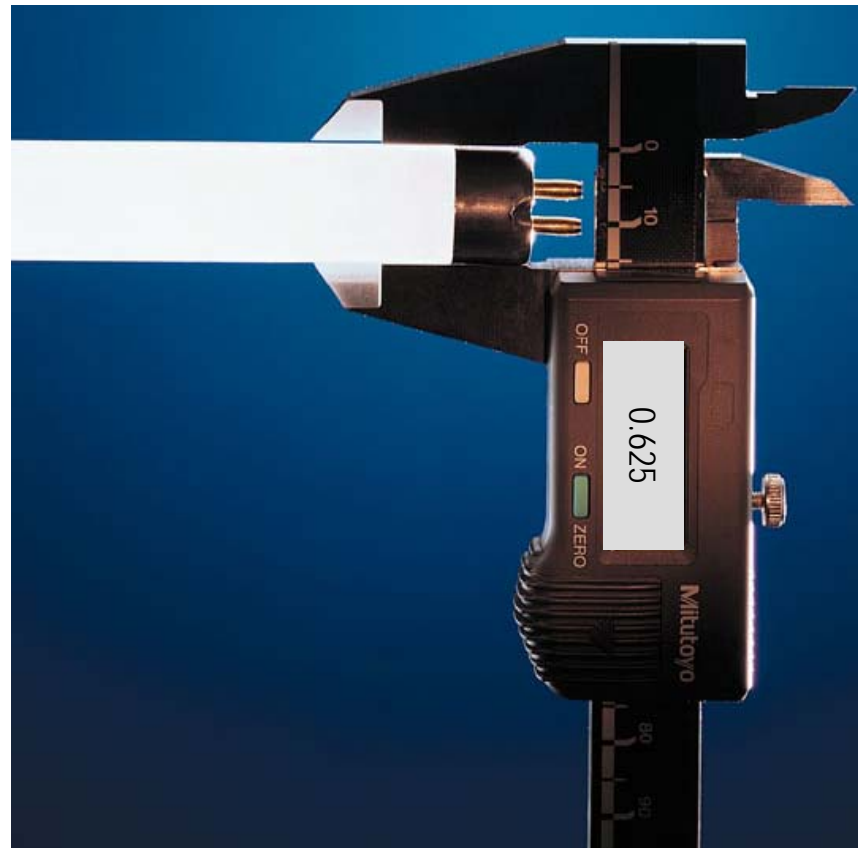


# Fluorescent Applications





## T5 Systems





## T5HO





## T5HO – Indirect





## T5 – Direct/Indirect

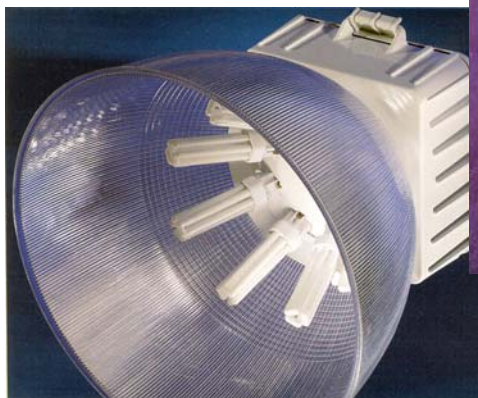






## CFL Systems

- Applications: downlights, wall washers, wall sconces, table lamps, floor lamps, pendants, low and high-bay industrial/sports lighting





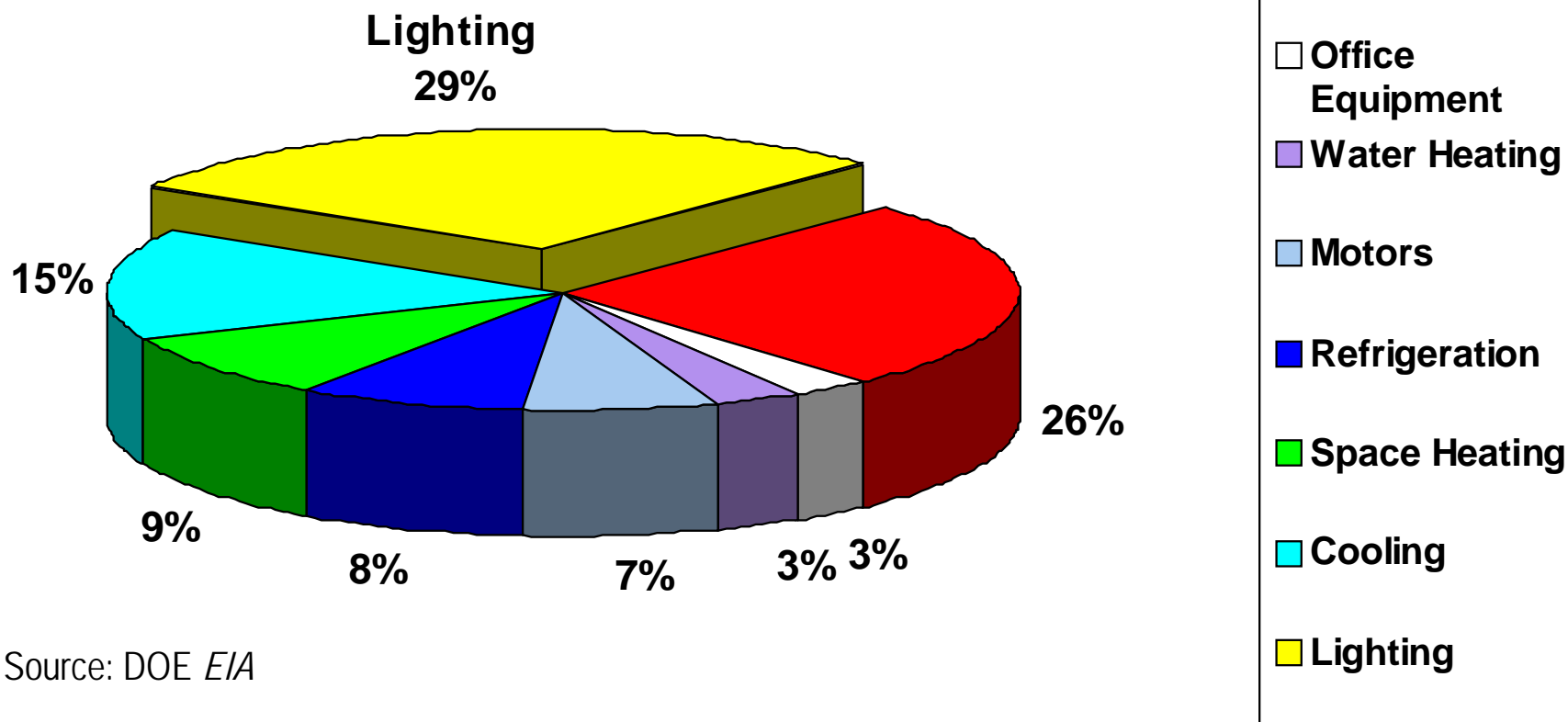


# Technologies

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# Energy Usage in Non-Residential Buildings





# Commercial Lighting Strategies

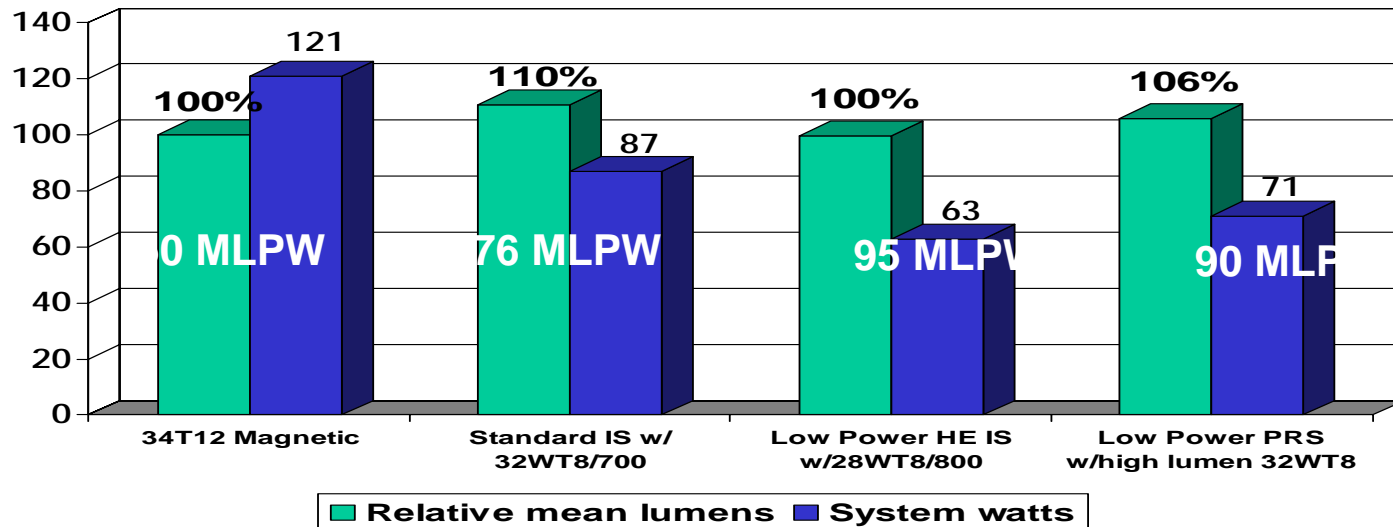
- Replace existing 32W T8 fluorescent lamps
  - *New* Lower wattage 28 or 30W T8
- Retrofit Standard T8 with “Enhanced” T8 fluorescent systems
  - *New* high efficiency instant start ballasts
- Retrofit Magnetic T12 with Electronic T8 fluorescent systems
  - *New* low power programmed rapid start ballasts
  - *Use* 28W/30W or higher lumen 32W lamps
- Install occupancy sensors/controls
  - Best way to save energy is to turn lamps off
  - Use programmed rapid start ballasts for best lamp life





3-lamp fixtures

# Fluorescent System Comparisons

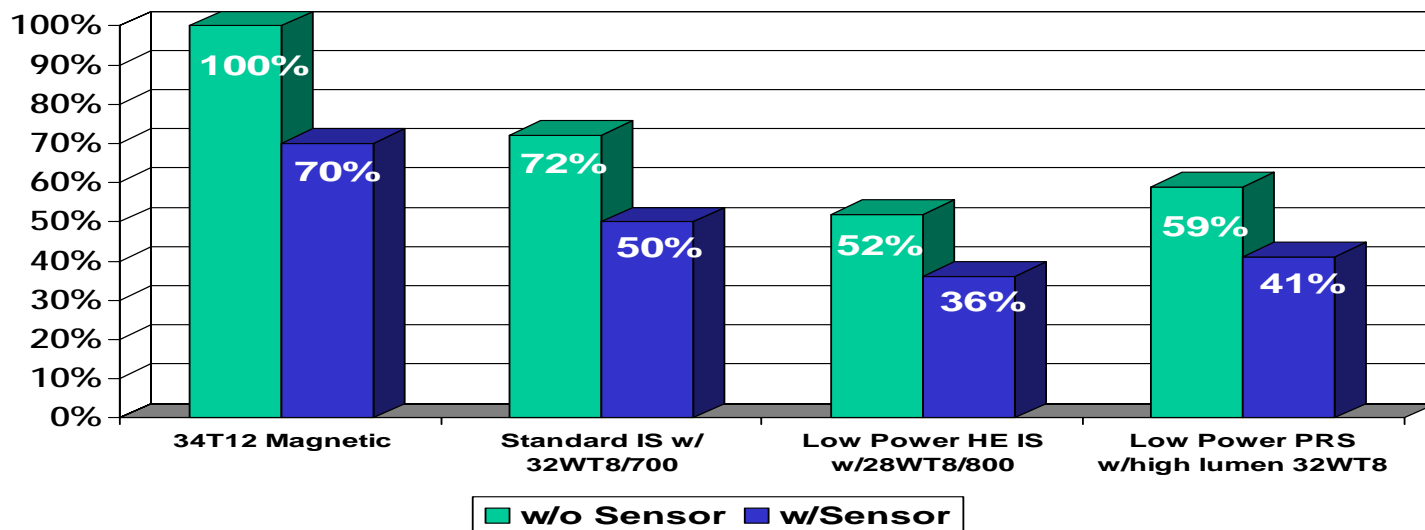




3-lamp fixtures

*Based on estimated 30% energy savings  
with use of occupancy sensors*

# Relative Energy Costs





# Average Rated Life – T8 Systems

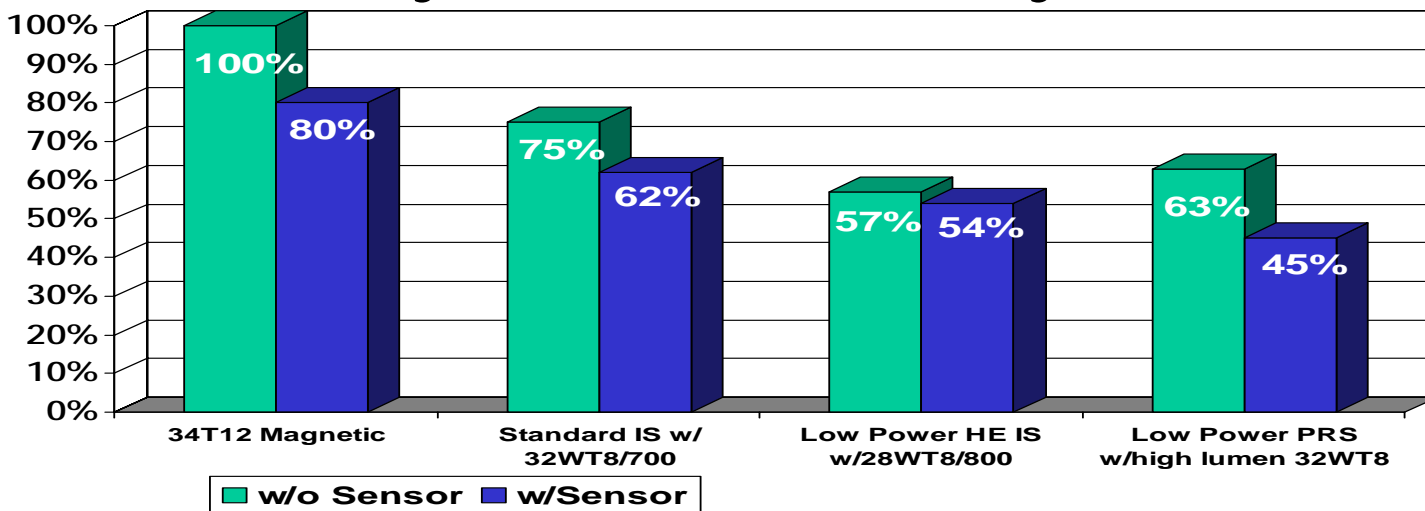
	15-30 minutes <u>per start</u>	12 hours <u>per start</u>
Standard IS ballast F32WT8/700	4000 – 7000 hrs	24,000 <sup>±</sup>
High Efficiency IS ballast F28WT8/800	4000 – 7000 hrs	30,000 <sup>±</sup>
Low Power PRS ballast High Lumen F32WT8/800	20,000 – 25,000 hrs	34,000 <sup>±</sup>



3-lamp fixtures

*Based on estimated 30% energy savings  
with use of occupancy sensors*

## Relative Life Cycle Costs – T8 Systems



**Assumptions:**

12 hours per start w/o occupancy sensors

15-30 minute shut-off w/ occupancy sensor



# High Bay Lighting Strategies

- Trends/New technologies/Industry Issues

- Multi-lamp fluorescent 6-8 T8 or 4-6 T5HO

- Occupancy sensor use
    - 1-4 lamp switchable ballast

- HID – Metal Halide

- Lower wattages: 320W, 350W & 360W replacements for 400W
    - Pulse start, Ceramic Arc-tube and Protech Metal Halide lamps

Improved color  
and lumen  
maintenance

Best color: High CRI,  
improved lamp to lamp  
color consistency and  
less color shift over life

As of January 2005, NEC  
requires all MH luminaires to  
be enclosed or use Protech  
lamps for new construction





# Street/ Area Lighting Strategies

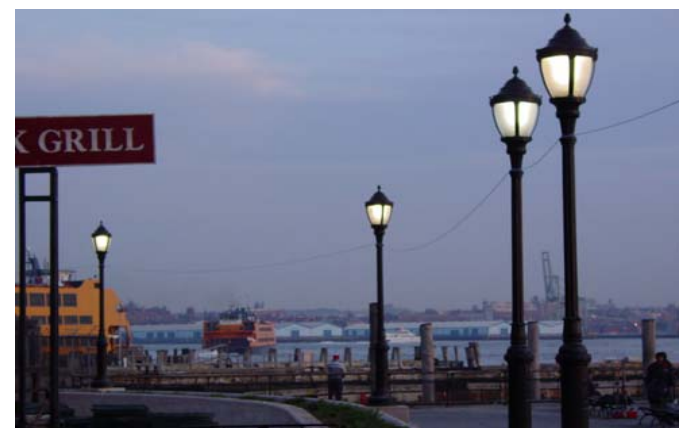
- Replace standard high pressure sodium lamps with non-cycling high pressure sodium lamps
  - Eliminates repeat trips to pole
    - Saves maintenance costs
  - 24,000-30,000 hours average rated life
- Replace M1000W Metal Halide lamps
  - 750W Pulse Start (requires ballast change) –
    - 25% Energy savings
  - *New* 900W (direct replacement) – BT56
    - 10% Energy savings





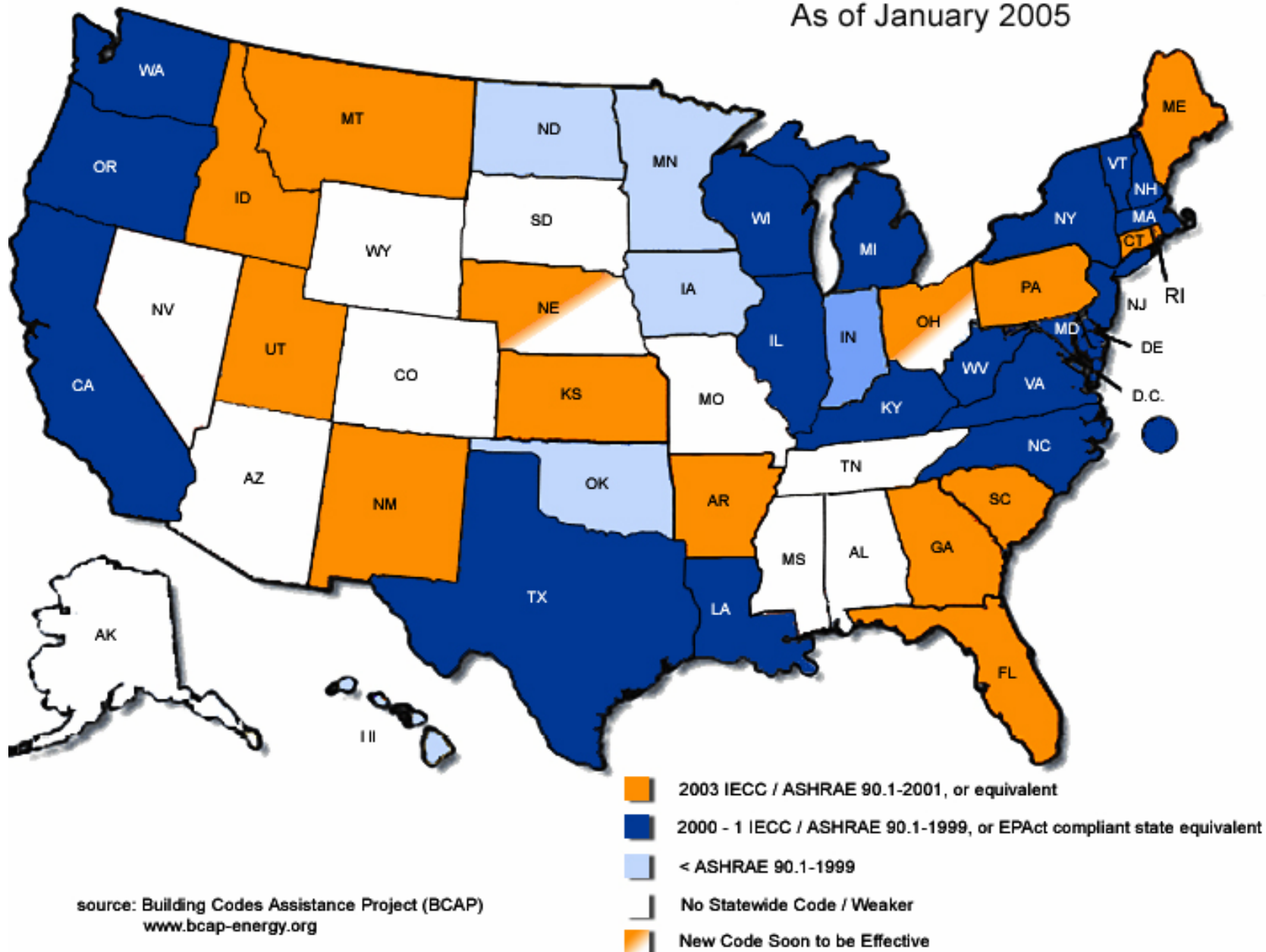
# Street/ Area Lighting Strategies

- Use “White” light sources for improved visibility
  - Metal halide
    - 7500 – 20,000 hours average rated life
  - Induction Systems – “Electrodeless” fluorescent
    - Instant on/Instant restrike
    - Up to 100,000 hours average rated life
      - 5-13 times longer life than HID Systems
    - 55W, 70W, 85W 100W, 150W & 165W



# Commercial State Energy Code Status

As of January 2005





# Impact of Energy Codes on Private Offices

- ASHRAE/IESNA Standard 90.1
  - Space-by-Space Method:
    - 1999 – 1.3 W/sq ft
  - Building Area Method:
    - 1999 – 1.5 W/sq ft
- CA Title 24, Part 6
  - Area Category Method
    - 2005 – 1.2 W/sq ft
  - Complete Building Method
    - 2005 – 1.1 W/sq ft

Private Office New Construction 2-lamp Systems	System Wattage	Watts per sq ft	Maint. fc
<i>Magnetic F34WT12 CW</i>	77	1.58	33.7
<i>Std Electronic IS F32WT8/700</i>	59	1.21	37.2
<i>Low Power HE IS F28/WT8/800</i>	42	0.86	33.6
<i>Low Power PRS High lumen F32WT8/800</i>	46	0.94	35.9



# LEED™ and Lighting

- Certification for New buildings (or major renovations)
  - Earn points in some or all of 6 LEED categories (69 points maximum)
- Energy & Atmosphere category relates to lighting
  - As a baseline, ASHRAE/IESNA Standard 90.1-1999 must be met
  - Buildings earn points for bettering this standard, as follows;

New Buildings	Existing Buildings	Points
15% better	5% better	1
20% better	10% better	2
25% better	15% better	3
30% better	20% better	4
35% better	25% better	5
40% better	30% better	6
45% better	35% better	7
50% better	40% better	8
55% better	45% better	9
60% better	50% better	10

Must use the lower whole building LPD values as the baseline, not space by space values